Draft: Potential Flood Hazards
Willow Beach

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POTENTIAL FLOOD HAZARDS AT WILLOW BEACH, LAKE MEAD NATIONAL RECREATION AREA

PREPARED FOR THE

NATIONAL PARK SERVICE

JULY 1980

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Prepared for

the

NATIONAL PARK SERVICE

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POTENTIAL FLOOD HAZARDS AT WILLOW BEACH, LAKE MEAD NATIONAL RECREATION AREA

INTRODUCTION

In the four-year period, 1976-1979, five flooding incidents were reported by the rangers at Willow Beach. Each incident involved some damage to National Park Service property and associated clean-up costs. In at least one case campers lost personal property as flood waters moved through the campground. Fortunately no loss of life from flooding has been reported. However, in September 1974, a major flood swept through Eldorado Canyon causing a loss of nine lives and extensive damage to fixed property, parked cars, mobile homes, and boats moored at the marina. Eldorado Canyon is about 12 miles south of Willow Beach on the west shore of Lake Mohave. The National Park Service wishes to have a reliable assessment of the flood risk at Willow Beach so that decisions regarding the continued operation of the unit in its present form can be made as required by Executive Order 11988.

The U. S. Geological Survey prepared flood plain maps for three washes in the Willow Beach unit, and on the basis of these estimates the National Park Service closed the campground located in Jumbo Wash and attempted to close the mobile home park located in Willow Beach wash. This closure

was contested in court and the court expressed doubt as to the reliability of the U. S. Geological Survey estimates and instructed the National Park Service to arrange for an independent review of the flood hazards there. The National Park Service contracted with Linsley,Kraeger Associates to review the U.S. Geological Survey estimates and, if necessary, to make new estimates of flooding potential in Jumbo, Access Road, Willow Beach, and Last Chance washes with the intent of considering the feasibility of flood mitigation and/or alternate facility plans which might be needed if the present facilities are unsafe from the viewpoint of flood hazard. This report summarizes the studies by Linsley, Kraeger Associates.

THE CATCHMENTS

The catchments under study are located at about latitude 35° 51' N, longitude 114° 37' W. They are left-bank tributaries of Lake Mohave in the state of Arizona (Fig. 1). Access Road, Willow Beach, and Last Chance Wash flow in a generally east-west direction. These three catchments are quite similar in size and general characteristics (Table 1). Jumbo Wash is, as its name implies, much larger than the other three washes and flows in a southeast-northwest direction. Data on drainage area, length, slope, and other physical characteristics is summarized in Table 1.

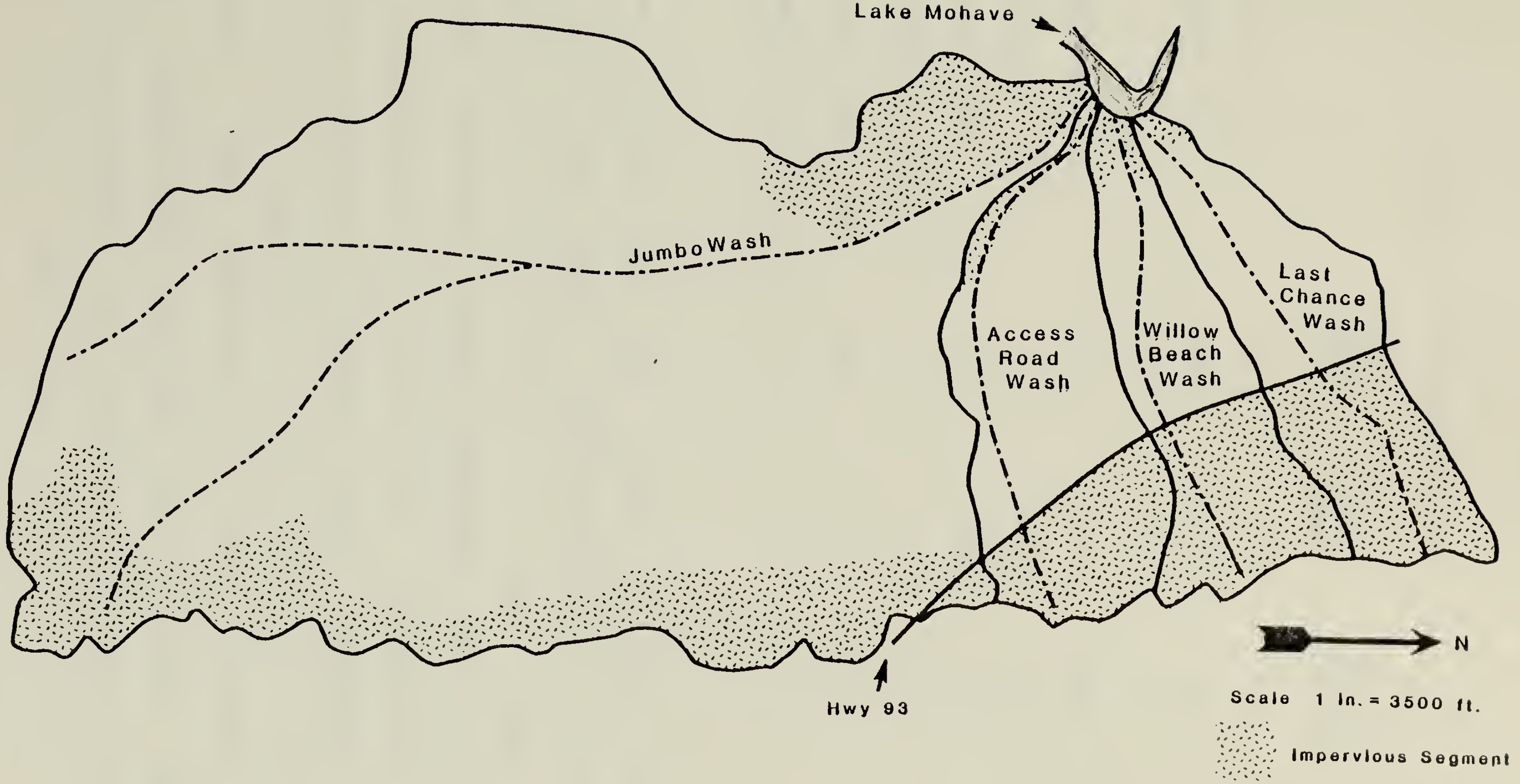

Fig. 1 Map of the Willow Beach washes

Table 1

Catchment Characteristics

	Jumbo Wash	Access Road Wash	Willow Beach Wash	Last Chance Wash
Drainage Area, sq.mi.	36.4	5.6	4.4	4.2
Channel Length, mi.	10.5	3.7	3.7	3.9
Lca, mi.	5.3	1.7	1.6	1.7
Maximum Elevation, ft.	3,360	3,200	3,424	4,094
Minimum Elevation, ft.	647	647	647	647
Channel Slope, ft/mi.	255	690	751	884
Impervious Segment, sq. mi.	8.4	1.9	2.4	2.0
Pervious Segment, sq. mi.	28.0	3.7	2.0	2.2
Effective Impervious Area, percent	11	14	21	19

The area is desert with mean annual rainfall varying from about six to eight inches. Because the area is situated between elevations 600 and 4100 ft. msl, winters are relatively cool with mean January temperature about 45°F but mean July temperatures are near 90°F. Vegetation on the basin is sparse consisting of desert grasses, sagebrush, and other low growing vegetation. The washes all rise in the Black Mountains. These mountains are largely andesite and granite and channels are generally deeply incised. West of Highway 93 the catchments consist mostly of alluvial fan with wide shallow channels which shift position during major

storms. Some of the upper channels may shift sufficiently that their flow is discharged to Lake Mohave via a different wash. There is a significant area between Access Road Wash and Jumbo Wash which can contribute to either wash depending on the configuration of a low divide between the washes.

Near Lake Mohave hard rock again dominates and the washes have cut canyons through these rocks on their way to the lake. Prior to filling of Lake Mohave, the washes entered the Colorado River at an elevation substantially lower than they do today. Hence the lower end of these channels has been filled with alluvium and the channel slope has been flattened (Fig. 2). The upper portion of each catchment consists of fractured granitic and andesitic rock with a thin soil cover of coarse sands and gravels on those ridges which have a sufficiently flat top and in the small fans and channels. Jumbo Wash also includes considerable exposed volcanics (basalt and tuff).

For the most part the exposed rock slopes are very steep (one horizontal to two vertical). In the alluvial fans, soils are coarse sands and gravels with most of the fines which may have once been present removed by water or wind. Consequently these soils should be highly pervious to water, especially in the channels. Interchannel areas are armored with stones which remain after the smaller materials are

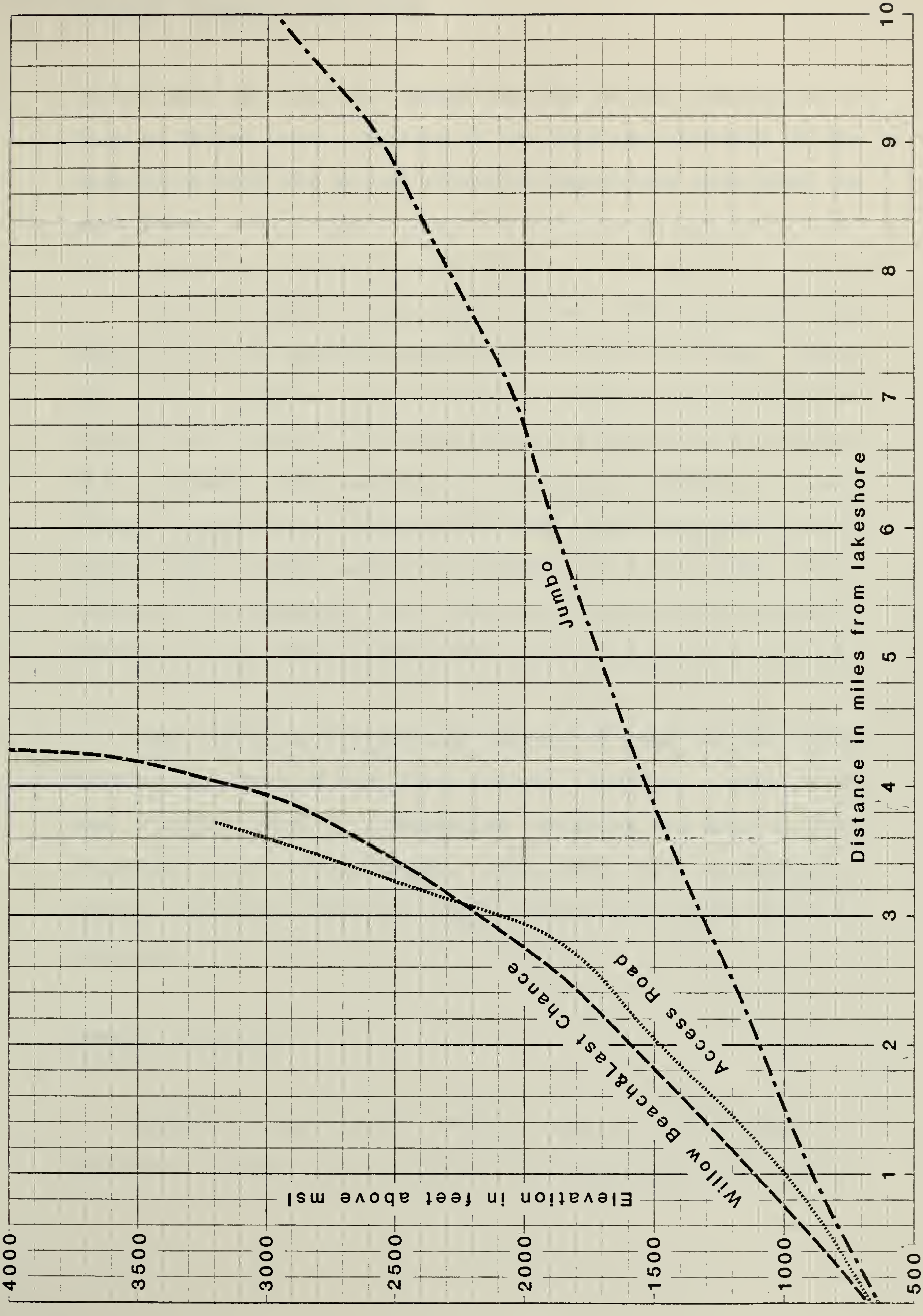

Fig.2 Channel profiles, Willow Beach washes.

washed away so that gross imperviousnes of the area may be as high as 70 per cent. Because of the high perviousness of the underlying soil the actual effective impervious area must be much lower.

As the washes narrow prior to their entrance into Lake Mohave, flow is confined between rock walls with side slopes of 1:2 or steeper and little or no soil cover except for locally flat areas on the ridge tops. Profiles of the washes show extremely steep slopes in the mountain headwaters, much flatter slopes in the alluvial fans, and steepening of the slopes again as the washes cut through the lower rocky zone. There is a tendency for the slope to flatten at the lake because of the rise in base level when the lake was filled.

The profile of the main channel of Jumbo Wash is much flatter than that of the other washes. However, Jumbo Wash has steeply sloping tributaries entering the main channel throughout most of its length. Jumbo Wash has a dendritic channel pattern while the other washes have a more fan-like pattern.

GENERAL HYDROLOGY

Rainfall occurs in the Willow Beach area during two seasons. Winter rain results from the passage of Pacific

frontal systems which have moved through California and Nevada. These fronts bring rain of moderate intensity which may last for several hours, and a series of frontal passages may continue for several days. Runoff rates are usually low but runoff may persist for several days. Occasionally during the winter months a tropical storm from the Pacific Ocean west of Mexico may penetrate the area. Usually however the most intense rains and those most likely to cause flash floods occur in the summer (July through September) with the most critical month being September. Moist maritime air from the Pacific enters the area when the circulation is favorable and convective thunderstorms occur when the combination of air mass stability and local topography are appropriate. Such storms may remain at the point where they form or they may drift with the local wind. These winds are most frequently from the western quadrant (NW to SW winds) but movement in any direction is possible.

Thunderstorms may vary in areal extent from a fraction of a square mile to 25 or more square miles. Combinations of multiple cells may seem to cause rain over relatively large areas.

ANALYTIC METHODS

Desert washes such as the four washes at Willow Beach pose difficult analytical problems for the hydrologist. No record of flow has been maintained on any of these washes. The closest long-term rainfall record is at Boulder city, Nev., about 13 miles northwest. The nearest recording gage record is at Searchlight, Nev., about 34 miles to the southwest. A short record exists at Willow Beach but a brief comparison shows that it does not indicate the rain over each of the washes because of the characteristically spotty rain during thunderstorms. These conditions preclude the classical approach of hydrology, namely to devise some relationship between local rainfall and local runoff.

Two general type approaches are available:

(1) To use some type of statistical procedure based on the streamflow records available in the region. This is called regional flood frequency analysis.

(2) To assume that rainfall from some nearby location can be ~~transferred~~ to Willow Beach and that the resulting flood flows can be computed by some appropriate hydrologic procedure.

Several different methods are possible within these two general approaches. Any method that is used will have some degree of uncertainty, because these methods will depend on

assumptions which are probably not completely accurate. We have used several methods and compared the results from these methods in an attempt to derive a "concensus answer" which may be superior to any one of the answers from a particular method.

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The computed peak flows by all methods are summarized in Table 7 and plotted as flood frequency curves in Fig. 4. The following sections describe each of the methods utilized and discuss the strengths and weaknesses of each method.

Regional Flood Frequency Methods

U. S. Geological Survey Regional Analysis. The original estimates by the Geological Survey were based on a regional frequency study [1]. This particular method utilized available streamflow records in the California desert area. Each record was analyzed to define the 2-, 5-, 10-, 25-, 50-, and 100-year floods at the station. Values of the floods for a particular return period from a number of stations were then correlated with parameters describing the catchment. The regression equation giving the best conformance with observed data was adopted. In this case the only significant parameter was the drainage area and the resulting equations are exponential (Table 4). This method is called GSCAL elsewhere in this report for brevity.

Table 2

The Equations for Peak Flow in the

South Lahontan-Colorado Desert Region of California[1]

Return Period yr	Values of K and a in $Q = KA^a$ K	a
2	7.3	0.30
5	53	0.44
10	150	0.53
25	410	0.63
50	700	0.68
100	1080	0.71

This approach makes several critical assumptions:

(1) That all catchments are similar except for the differences in drainage area. Actually soil type, topography, vegetation, elevation, and precipitation differences could be important. In effect, it has been assumed that flood peaks are an exponential function of drainage area which is a rather simplified view of the process in nature.

(2) In applying this method to Willow Beach it is assumed that data from eastern California deserts of the Colorado and Lahontan area are applicable to the northwest of Arizona. If drainage area were truly the only catchment characteristic of importance, this would be a valid assumption. Actually there are significant differences. One third of the catchments used in deriving the equations were at elevations greater than 3000 feet, one third of the catchments had rain in excess of 6 inches per year, and half the catchments were less than one square mile in area. Other important soil and vegetal cover differences also exist.

(3) That the relatively short records of flow available correctly define the flood peaks at the stations for the several return periods. Generally short records are unreliable for frequency analysis. The estimates are more likely to be high than low.

The results of this method are summarized in Table 7 and in the frequency plots. Discussion of the accuracy of the results appears in a later section.

The Arizona Department of Transportation Method. A report dealing with flood frequency in Arizona was prepared by the U. S. Geological Survey for the Arizona Department of Transportation. This method is designated GSADOT for reference in this report. The procedure was virtually identical to that described under GSCAL and the method is subject to the same assumptions except for number (2). GSADOT utilized data from Arizona including stations in the northwest corner of the state. Unfortunately there are very few stations close to Willow Beach. Three stations are in the Kingman, Ariz. area. Most of the stations used for the northwest Arizona region are located in the upper Gila basin near Flagstaff and the central Little Colorado basin near Page, Ariz. Significant geological and climatic differences exist between these stations and Willow Beach. The equations for northwest Arizona are given in Table 3.

Table 3

Flood Frequency Equations for Northwest Arizona

Arizona Department of Transportation Study

Return Period yr	Values of K and a in $Q=KA^a$ K	a
2	19.0	0.660
5	66.3	0.600
10	127.	0.566
25	252.	0.532
50	393.	0.510
100	584.	0.490
500	1,300.	0.451

<u>Rainfall-runoff models.</u>

Two different approaches using a rainfall-runoff model were tried. The model employed was a version of the Stanford Watershed Model (SWM). This model uses rainfall data as input and simulates interception, impervious area runoff, channel routing and the other processes of the runoff cycle. The model is adjusted to the catchment under study by setting a number of parameters to accord with catchment characteristics. If possible the model is tested by simulating flows for a period when measured flows are available and the parameters calibrated by trial until the observed flows are closely simulated. In this case no measured flows were available. However, rainfall data from Willow Beach concurrent with the several flooding incidents

were available, and an approximate calibration was effected using these data.

The parameters selected for the watersheds are listed in Table 4 for three trials, A, B, and C. They have been arranged in two groups. Group one are the parameters which dominate the simulation process under desert conditions. These parameters are the percentage impervious area, the upper and lower zone moisture storage capacity, and the infiltration and interflow parameters. These parameters were tested on the several data sets. Group two are those parameters which are significant and for which values have been assigned from map analysis or field inspection. These include the interception storage,and the length, slope and roughness of overland flow. Finally there are several parameters which are not relevant in this study. No interflow or groundwater flow is assumed to occur and hence the interflow and groundwater recession factors have no significance. Calculations are made over a period of a few hours and evaporation and evapotranspiration are not significant. Finally it is assumed that we are dealing with true rainfall and the rainfall correction factor is not significant. Values for this group of parameters are not included in Table 4.

TABLE 4

SWM Parameters

Parameter		Segment 1 A	Segment 1 B	Segment 1 C	Segment 2 A	Segment 2 B	Segment 2 C
KEY PARAMETERS							
A	Impervious fraction	0.7	0.35	0.35	0.04	0.04	0.04
UZSN	Upper zone, in.	0.1	0.10	0.15	0.25	0.25	0.25
LZSN	Lower zone, in.	2.0	2.0	6.0	6.0	6.0	6.0
INFIL	Infiltration, in/hr	0.25	0.25	0.44	0.44	0.44	0.44
INTER	Interflow fraction	0	0	0	0	0	0
PHYSICAL PARAMETERS							
EPXM	Interception	0.05	0.05	0.05	0.05	0.05	0.05
L	Overland flow length,ft.	75.	75.	75.	75.	1000.	1000.
SS	Overland flow slope, ft/ft	0.1	0.1	0.1	0.1	0.1	0.1
NN	Overland roughness	0.3	0.3	0.3	0.3	0.3	0.3

The catchments are assumed to consist of two segments. Segment 1 represents the hard-rock areas and is called the "impervious segment". Segment 2 represents the alluvium and is the "pervious" segment. It will be seen that Segment 1 has a much higher impervious fraction, slightly lower upper zone storage, and much shorter overland flow length. With the aid of a geologic map [3], aerial photographs, and notes from a field inspection, each catchment was divided into the two segments (Table 1 and Fig. 1).

The flooding incidents at Willow Beach were simulated using the reported rainfall from Willow Beach in whatever detail reported by the ranger for the Access Road and Willow

Beach washes. Parameter set A yielded flows which appeared to be much too high for the relatively minor events which occurred. Hence, set A was not given further consideration. Parameter sets B and C gave almost identical flows for the lesser floods and these flows appeared to be reasonably consistent with the ranger's description of the incident. At the low flow range the simulated flows were reasonably consistent with the 1-and 2-yr floods from GSCAL and GSADOT. Hence, parameter sets B and C are considered plausible sets for the Willow Beach washes.

The model was used to generate flood series for each of the four washes using two sets of rainfall data. The first set was from NOAA Atlas 2, Precipitation Frequency Atlas for the Western States [4]. This atlas provides estimates of the 24-hr rainfall for return periods of 2-, 5-, 10-, 25-, 50-, and 100-yr, and procedures to reduce this rainfall to durations from 5 minutes to 12 hours. These procedures were used to develop a 24-hr rainfall sequence for each return period. The atlas also includes procedures for adjusting the rainfall amounts for the size of the drainage area. The three small catchments are so nearly equal in size that the same rainfall was used for all three catchments (Table 5). The maximum 6 hours of these rainfall sequences was used as input to the simulation model. Runs were made using both parameter sets B and C.

Table 5

Rainfall Intensities for Small Catchments, inches

Return Period	Duration 5m	10m	15m	30m	1h	2h	3h	6h	12h	24h
2	0.27	0.45	0.62	0.74	0.93	1.02	1.10	1.20	1.30	1.40
5	0.33	0.51	0.65	0.90	1.16	1.40	1.50	1.70	1.80	2.00
10	0.39	0.60	0.76	1.00	1.36	1.60	1.70	2.00	2.20	2.40
25	0.46	0.72	0.92	1.20	1.65	2.00	2.10	3.40	2.70	3.00
50	0.55	0.86	1.04	1.50	2.00	2.22	2.40	2.80	3.10	3.40
100	0.68	1.04	1.30	1.90	2.40	3.00	3.10	3.20	3.40	3.80

Table 6

Rainfall Intensities for Jumbo Wash, inches

Return Period	Duration 5m	10m	15m	30m	1h	2h	3h	6h	12h	24h
2	0.24	0.36	0.47	0.69	0.88	0.94	1.00	1.20	1.20	1.40
5	0.33	0.51	0.65	0.90	1.16	1.40	1.50	1.70	1.80	2.00
10	0.39	0.60	0.76	1.00	1.36	1.60	1.70	2.00	2.20	2.40
25	0.46	0.72	0.92	1.20	1.65	2.00	2.10	2.40	2.70	3.00
50	0.55	0.86	1.04	1.50	2.00	2.20	2.40	2.80	3.10	3.40
100	0.68	1.04	1.30	1.90	2.40	3.00	3.10	3.20	3.40	3.80

The second source of rainfall data was from the National Weather Service recording rain gage at Searchlight, Nevada which is about 13 miles southwest of Willow Beach. A 25-yr record of hourly rainfall was developed from the available data for the period 1952 to 1976. This 25-yr record was input to the simulation model, annual peaks for each year were determined, and the resulting data series analyzed for

flood frequency.

The principal assumptions involved in this approach to the development of flood frequency are:

(1) That the n-year rainfall will produce the n-year flood. This assumption is questionable in many areas beacause of the variable conditions which may precede the storm. However, given the high evaporation and the relative infrequency of rainfall in the southwestern desert region, it seems reasonable to assume that all rainfalls occur on uniformily dry soil. If this assumption is in error, the resulting peaks will have return periods greater than those of the rainfall.

(2) That it is possible to arrive at reasonable assumptions as to the parameters of the rainfall-runoff model. Because of the peculiar character of these desert catchments, it appears that the most important parameter is the effective impervious area. Our crude calibration seems to indicate that the selected value for impervious area is reasonable.

(3) That the rainfall recorded at Searchlight, Nev. is representative of rainfall that might have occurred over any of the Willow Beach washes. Given the close proximity of Searchlight to Willow Beach and the fact that both locations seem to have about the same mean annual precipitation it is believed that this is a valid assumption.

COMPARISON AND ASSESSMENT OF THE FLOOD FREQUENCY ESTIMATES

The results of flood estimates by each of the methods described above are tabulated for all washes in Table 7.

Table 7

Calculated Peak Flows Various Return Periods, cfs

From Geological Survey California Study

Return Period	2	5	10	25	50	100
Access Road	12	113	374	1214	2259	3670
Willow Beach	11	102	329	1043	1917	3092
Last Chance	11	100	321	1013	1857	2992
Jumbo	22	258	1008	3947	8066	13861

From Geological Survey Arizona Study

Access Road	59	186	337	630	946	1358
Willow Beach	51	161	293	554	837	1207
Last Chance	49	157	286	541	817	1180
Jumbo	204	573	971	1706	2458	3399

From NOAA Precipitation Data with Parameter Set C

Access Road	336	484	563	754	975	1195
Willow Beach	395	590	688	887	1141	1439
Last Chance	348	510	595	786	969	1282
Jumbo	474	1110	1480	2054	2370	2685

From NOAA Precipitation Data with Parameter Set B

Access Road	336	541	707	1214	2259	3670
Willow Beach	396	644	848	1402	2235	2770
Last Chance	348	538	754	1180	1873	2373
Jumbo	727	1080	1980	2660	4025	6544

From Searchlight Rainfall Data

Access Road	207	408	578	727	853	979
Willow Beach	340	459	622	869	1027	1177
Last Chance	150	400	562	822	980	1138
Jumbo	474	1110	1420	2054	2370	2685

The flow frequency curves for Access Road Wash are shown for all methods in Fig. 3. Our analysis of these results is as follows:

(1) The very considerable difference between GSCAL and GSADOT indicates that only one of these can be right. The estimates from GSADOT are specifically applicable to the Willow Beach area and are much more consistent with the other methods displayed. Hence, we believe that the GSCAL procdure should be rejected for this analysiss. Unfortunatley the GSADOT study was not available when the Geological Survey made their analsis of flood potential for Willow Beach and the GSCAL study was the only regional frequency procedure available.

(2) The Searchlight data yields lower peaks at all return periods than do either of the other rainfall-runoff methods (NWS-SWM B and NWS-SWM C). This situation seems to result from a fundamental problem in the use of published hourly rainfall data for small watersheds which respond to very short duration, high intensity rain. Since the hourly data is published on a clock-hour basis, any rainfall which extends across a clock-hour is distributed to two hours. Thus, one inch of rainfall occurring between 3:45 and 4:45 at an actual intensity of two inches per hour, is published as two one-hour amounts of 0.50 inches. This causes the caculated peak to be much lower than it should be. Even if the 30-minute rainfall had occurred entirely within an clock-

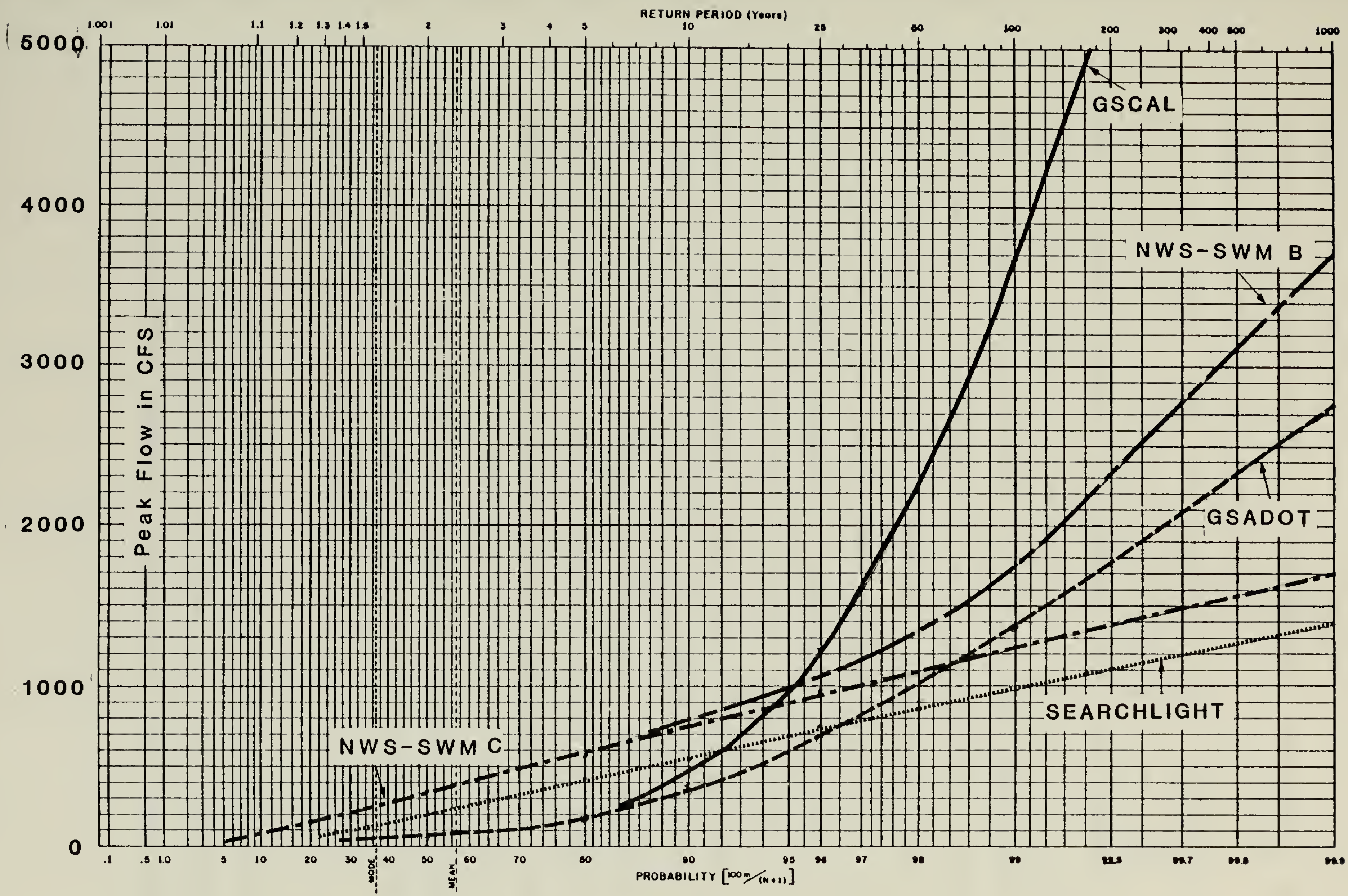

Fig. 3 Comparison of results by different methods for Access Road Wash

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hour, the apparent intensity is one-half of the actual intensity. Consequently, the flood peaks computed from the Searchlight data are probably low.

(3) Clearly the two methods using National Weather Service rainfall frequency data cannot both be right since they assume different parameters for the rainfall-runoff model. The difference between the two curves is caused by the differing assumptions as to UZSN, LZSN, INFILTRATION and L in Segment 1. Assuming that we have correctly indentified the impervious fraction in Segment 1, there is little reason to assume that the hydrologic behavior of the pervious portion of this segment is different than that of the pervious segment. Because land slopes are steeper in the areas of rock exsposure we have used a slighlty lower value of UZSN although the effect of this difference will be small. Also because the land slopes of Segment 1 are steeper, the length of overland flow is much less than in Segment 2. A long overland flow path means that surface runoff which may occur is exposed to delayed infiltration during the time required for the water to reach a channel. Indeed, in Segment 2 the channels are not greatly different in character than the overland flow plane.

Thus, despite the fact that the infiltration and lower zone storage parameters are the same in both segments, the runoff volume from segment 2 is much less than from segment 1

in the range of rainfall intensity up to the 100-yr frquency. We therefore believe that the estimates based on parameter set C are the more reliable estimates as compared to those made with set B.

(4) The comparison thus far has reduced the selection of acceptable frequency curves to two choices--GSADOT and NWS-SWM C. The latter method gives peaks approximately 10 percent higher for Willow Beach, Last Chance, and Jumbo washes and for many return periods on Access Road Wash. This is, by hydrologic standards, very good agreement and either procedure could be accepted. Since the simulation approach gives generally higher flows on all washes it is recommended as the more conservative approach.

The resulting frequency curves are shown in Fig. 4.

PROBABLE MAXIMUM FLOOD

A widely used basis for evaluating the safety of dams is the Probable Maximum Flood (PMF). This flood also receives special mention in the NPS policy with respect to flood hazard. Accordingly we have calculated the PMF for all washes.

The usual procedure is to estimate the Probable Maximum Precipitation (PMP) and to convert this storm into the PMF by

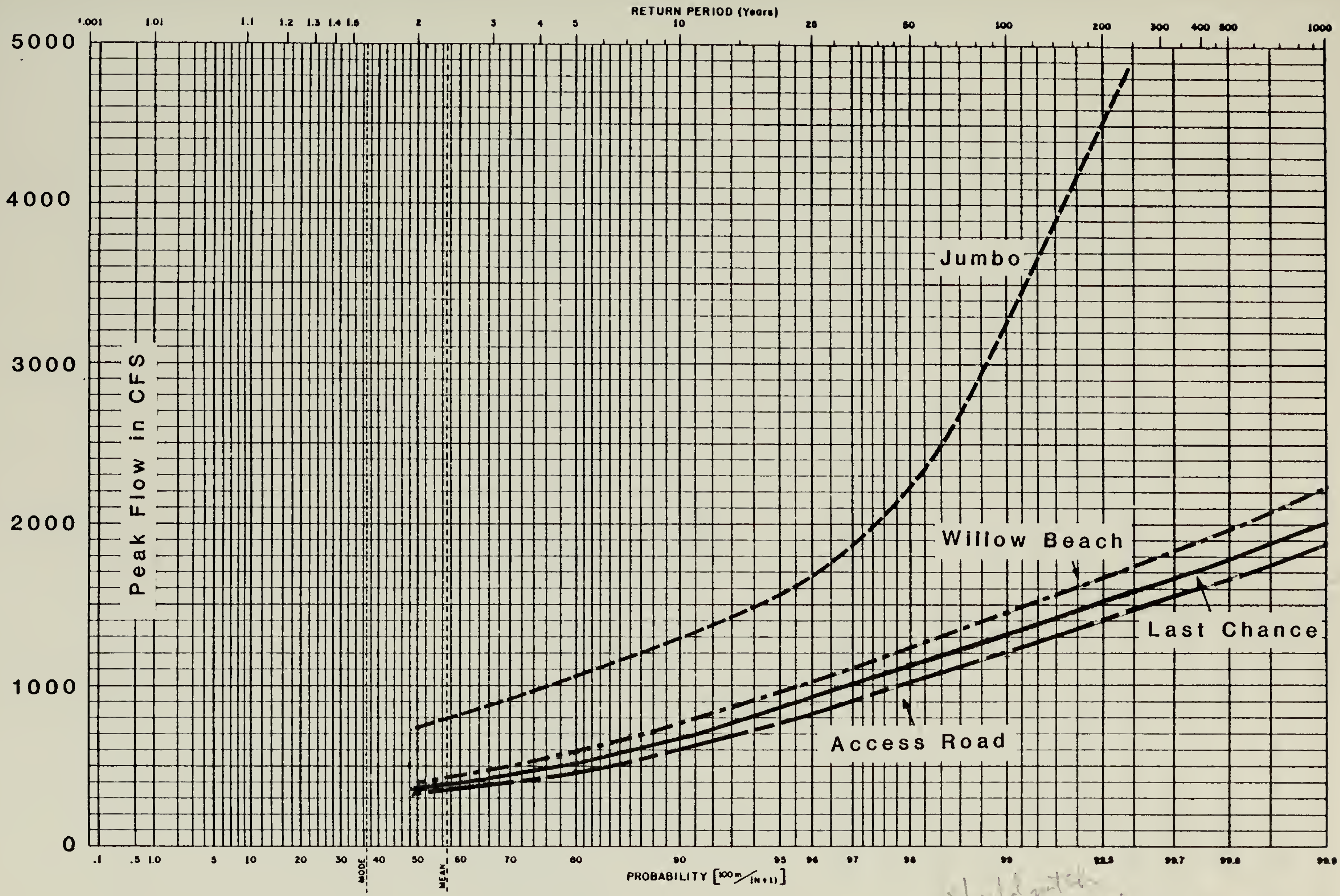

Fig. 4 Flood Frequency Curves for the Willow Beach Washes

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suitable hydrologic methods. The National Weather Service has published a report [5] which provides the methodology for estimating the PMP rainfall for a given catchment. The procedure enables estimates of the PMP convergence rainfall which might result from a general storm over the area and a Local Storm PMP caused by a convective thunderstorm. For the small catchments under consideration in this study the Local Storm PMP is much more severe than the convergence PMP. The derived rainfall amounts and durations up to 6 hours are given in Table 8 for the individual washes. Note that the 15 min. rainfall of the PMP equals or exceeds the 100-yr 24-hr rainfall in all washes!

Table 8

PMP Rainfall for the Willow Beach Washes

Wash	Duration								
	15m	30m	45m	1h	2h	3h	4h	5h	6h
Access Road	5.9	7.3	8.0	8.5	9.9	10.6	11.0	11.4	11.6
Willow Beach	6.1	7.6	8.3	8.8	10.2	10.9	11.3	11.7	11.9
Last Chance	6.1	7.6	8.3	8.8	10.2	10.9	11.3	11.7	11.9
Jumbo	3.7	5.1	5.7	6.3	7.5	8.2	8.8	9.2	9.8

Table 9

Probable Maximum and 500-year Flood Peaks,

Willow Beach Washes

Wash	Peak Flows		
	500-yr flood cfs	Probable Maximum Flood cfs	cfs/sq mi
Access Road	1650	17,500	3120
Willow Beach	1980	16,000	3640
Last Chance	1800	15,000	3570
Jumbo	6100	71,800	1970
Eldorado	----	70,000*	3210

* Estimated peak of 1974 flood

We have transformed the PMP rainfall into runoff hydrographs using the SWM system and parameter set C. The resulting peak flows are given in Table 9. The PMF peaks illustrate the fact that with sufficient rainfall to satify the soil moisture deficiencies which are usual in the desert, extraordinary floods can result. The PMF floods range from about 11 to 17 times the 100-yr flood. It is a matter of interest that the computed flows for the Willow Beach Washes are roughly equal to the estimated peak flow during the Eldorado Canyon flood of September 1974 when expressed in cubic feet per second per square mile. It would be expected that the smaller catchments at Willow Beach would have higher flows per unit area. Thus the Eldorado Canyon event may have approached the PMF.

Since the 500-yr flood sometimes enters decision-making

regarding flood problems, values of thr estimated 500-yr peaks are included in Table 9. No estimates of the 500-yr rainfall intensities are available. Hence, we have estimated the flood peaks from the frequency curves of Figure 4.

SEDIMENT AND DEBRIS

Each of the incident reports from Willow Beach notes that considerable amounts of sediment were brought down by each runoff event. Sediment transport typically varies as a power of the flow rate. Thus one may expect that the occurence of the lower frequency floods (25 to 100 yr) will transport vastly more sediment and debris than has ever been experienced in the few years that the Willow Beach facility has been operating. There are many equations for predicting the movement of bed sediment. Answers from these equations can differ by more than an order of magnitude when applied in a relatively simple case. In the desert washes, the location of the storm center, the formation of temporary gravel dams, obstacles in the flow, variable slope and flow rate all contribute to very large uncertainty as to the sediment transport.

Any attempt to compute the actual sediment load to be expected in these washes would be futile. It is more realistic to say that the 100-yr flow will transport at least 20 to 40 times as much sediment as any of the minor floods

experienced in the area since the Willow Beach facility has been operating. Most of the sediment will be deposited near the lakeside where the slope is quite flat and much will deposit wherever obstacles (buildings, shrubs, walls, etc.) create a local area of low velocity. Excavating the channels deeper as they approach the lake causes a flattening of the slope near the lake and increases deposition. Hence, the early sediment load will almost certainly fill the channels to an approximate equillibrium condition so that the peak flow is likely to occur on a much shallower channel.

The combined velocity of flow and sediment load means that persons caught in the flood water will have a very low chance of survival.

FLOOD PLAIN BOUNDARIES

The elevation of the flood at each of several cross-sections was calculated using the critical-depth for each flow rate at the cross-section. The calculations ignore the effect of major obstructions such as mobile homes and buildings because it is difficult to estimate the effect of such obstructions and because it is uncertain whether the obstruction will remain in place. It is certain, however that any obstructions in the flow will cause somewhat higher elevations than those calculated.

The effect of bulking of the flow with sediment has also

been ignored. The quantity of sediment transported under normal flow conditions is usually not sufficient to cause much bulking. However, in desert washes waves of sediment sometimes form a temporary dam which is eventually overtopped causing a surge of water and sediment to move downstream. Such conditions are virtually unpredictable but, as with obstructions, the effect is always to increase the stage. Thus the computed elevations given in Table 10 can be viewed as minimum likely elevations with the prospect that actual elevations will be somewhat higher. Plates 1 through 4 present cross-sections and plan maps showing estimated elevations for the various frequencies in the downstream section of each wash.

Since the occupied portions of the facility are generally in the canyons where the washes cut through the rock exposures near the lake, the significance of the flood plain mapping can be stated as follows:

> Floods with return periods of 5- to 25-years generally exceed the channel capacity and begin to spread out across the canyon floor. This would be hazardous for childern and handicapped, or campers caught by surprise during the night.
>
> Floods with return periods of 50- to 100-years will flood the canyons from cliff to cliff. On Access Road Wash this condition can develop with the 5-yr flood or less.
>
> The 500-yr event floods the canyons from wall to wall but flow depths are somewhat less-- 12-15 ft.
>
> The probable maximum flood will fill the canyons from wall to wall to depths of 15 to 20 ft. Chances of survival would be near zero.

Table 10

Flood Plain Elevations

RETURN PERIOD	SECTION A	B	C	D
Access Road Wash				
2	689.8	748.8	806.4	
5	690.2	749.8	806.9	
10	690.7	749.9	806.8	
25	690.9	750.1	807.1	
50	691.1	750.4	807.4	
100	691.2	750.6	807.4	
500	691.7	751.1	807.8	
PMF	698.2	759.5	820.1	
Willow Beach Wash				
2	673.6	698.1	711.9	726.0
5	674.0	698.4	712.1	726.2
10	674.4	698.5	712.2	726.4
25	675.0	698.6	712.4	726.6
50	676.0	698.8	712.6	726.9
100	676.5	698.8	712.9	727.1
500	677.3	699.3	713.3	727.5
PMF	682.2	704.3	719.8	733.9
Last Chance Wash				
2				
5				
10				
25				
50				
100				
500				
PMF				
Jumbo Wash				
2	668.5	701.7	756.5	824.3
5	668.6	702.2	756.9	824.7
10	668.9	702.8	757.6	825.4
25	669.2	702.8	758.3	826.1
50	669.5	703.5	759.1	826.8
100	670.0	704.0	760.1	827.8
500	671.0	705.2	762.0	830.2
PMF	680.7	715.3	772.3	845.7

The present flood hazard is high for facilities as they presently exist at Willow Beach. If sediment or debris should block the existing channels, even relatively minor floods could innundate the campground or trailer area.

FLOOD HYDROGRAPHS

Design of reservoirs for flood reduction requires some knowledge of the shape of the flood hydrograph. Figures 5 through 8 present the hydrographs for the 10-yr and 100-yr events and for the PMF. Table 11 summarizes the volume of runoff in the maximum hour of each flood.

Table 11

Runoff Volume During the Maximum Hour

Return Period	Flood volume in acre-feet			
	Access Rd.	Willow Bch.	L. Chance	Jumbo
2	23	29	25	57
5	35	41	36	82
10	42	49	42	113
25	53	62	54	133
50	64	66	59	174
100	82	95	83	247
PMF	955	866	819	4820

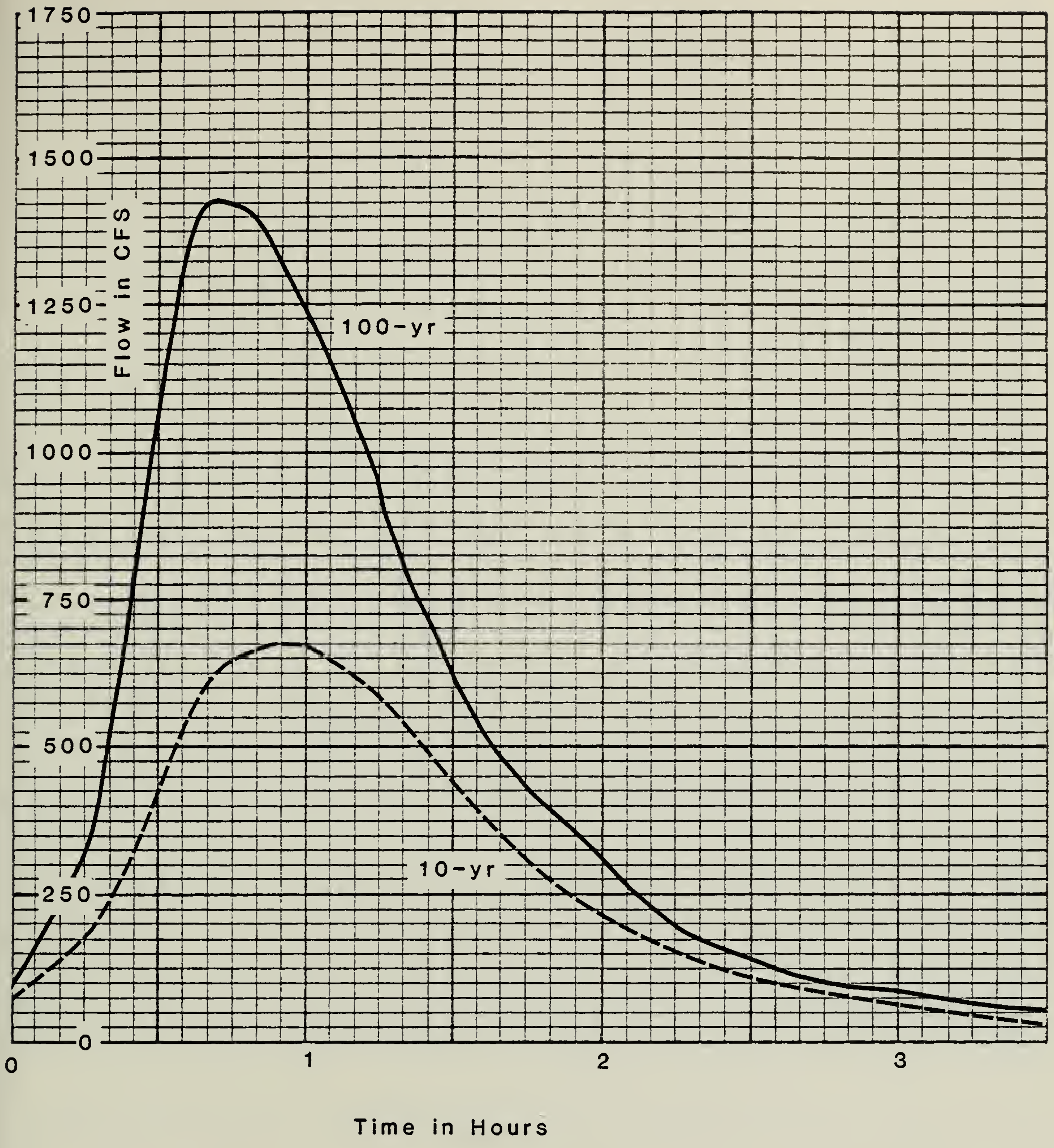

Fig. 5 Hydrographs of the 10- and 100- year floods on Willow Beach Wash

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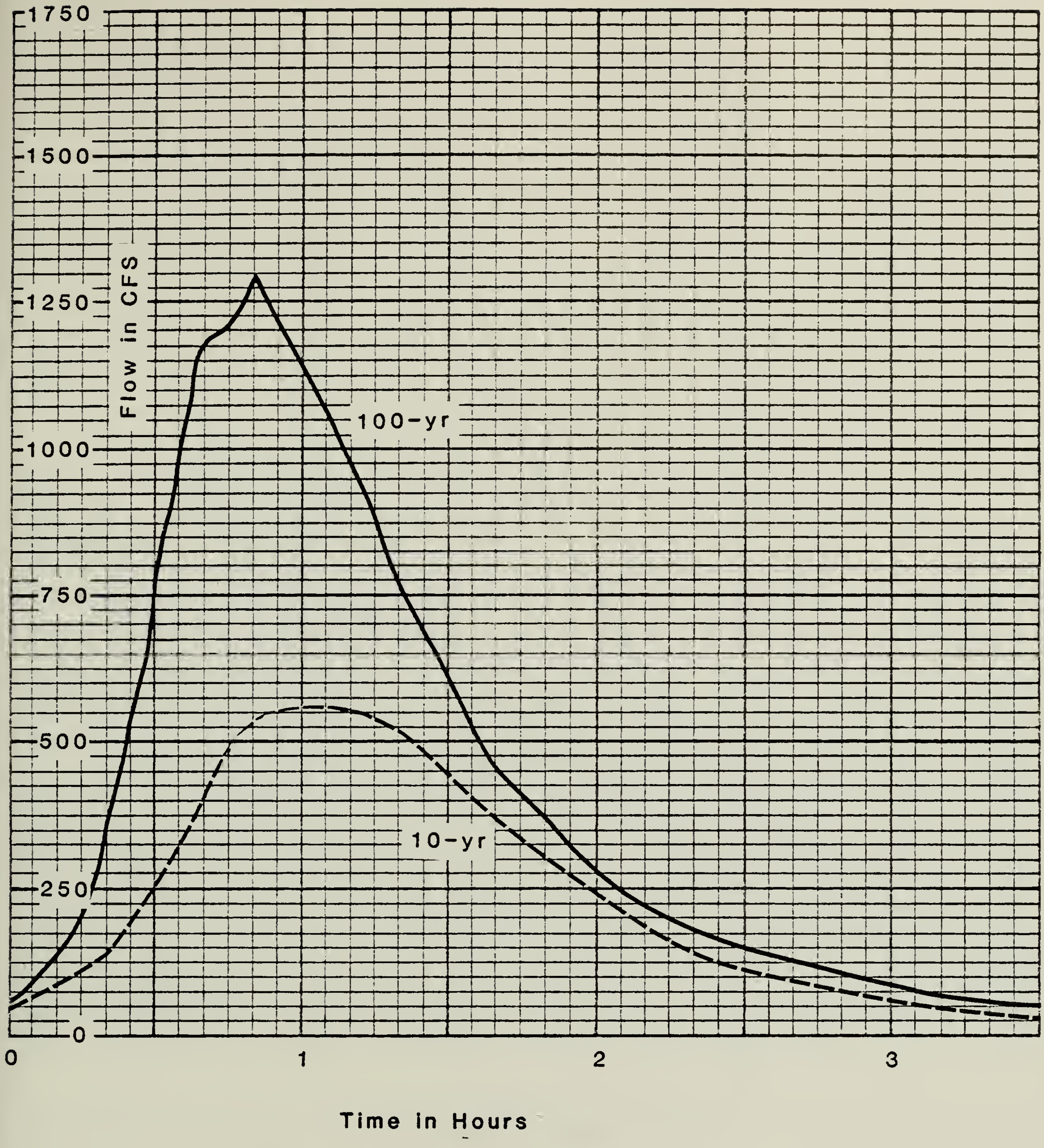

Fig. 6 Hydrographs of the 10- and 100-year floods on Last Chance Wash

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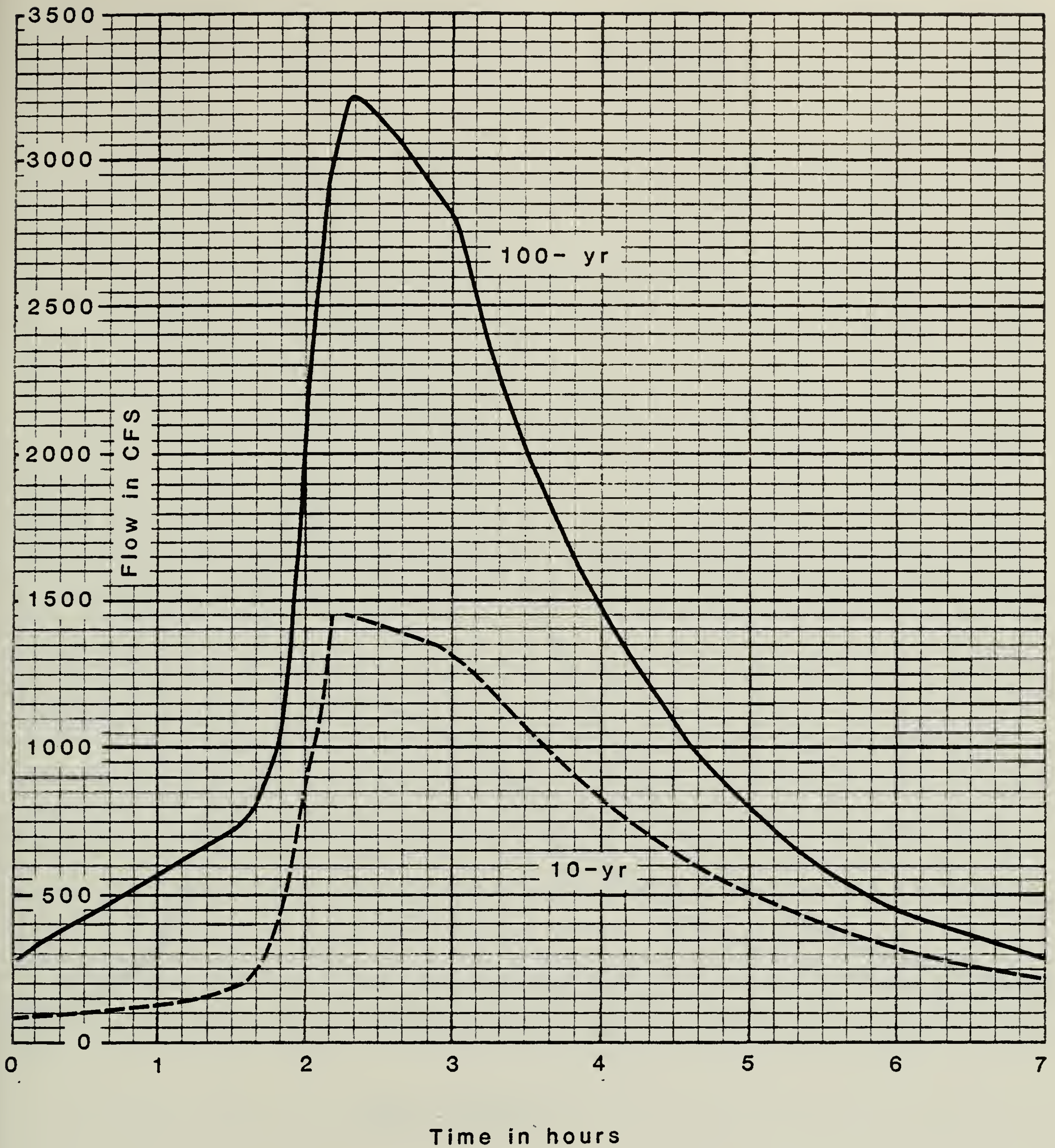

Fig. 7 Hydrographs of 10- and 100- year floods on Jumbo Wash

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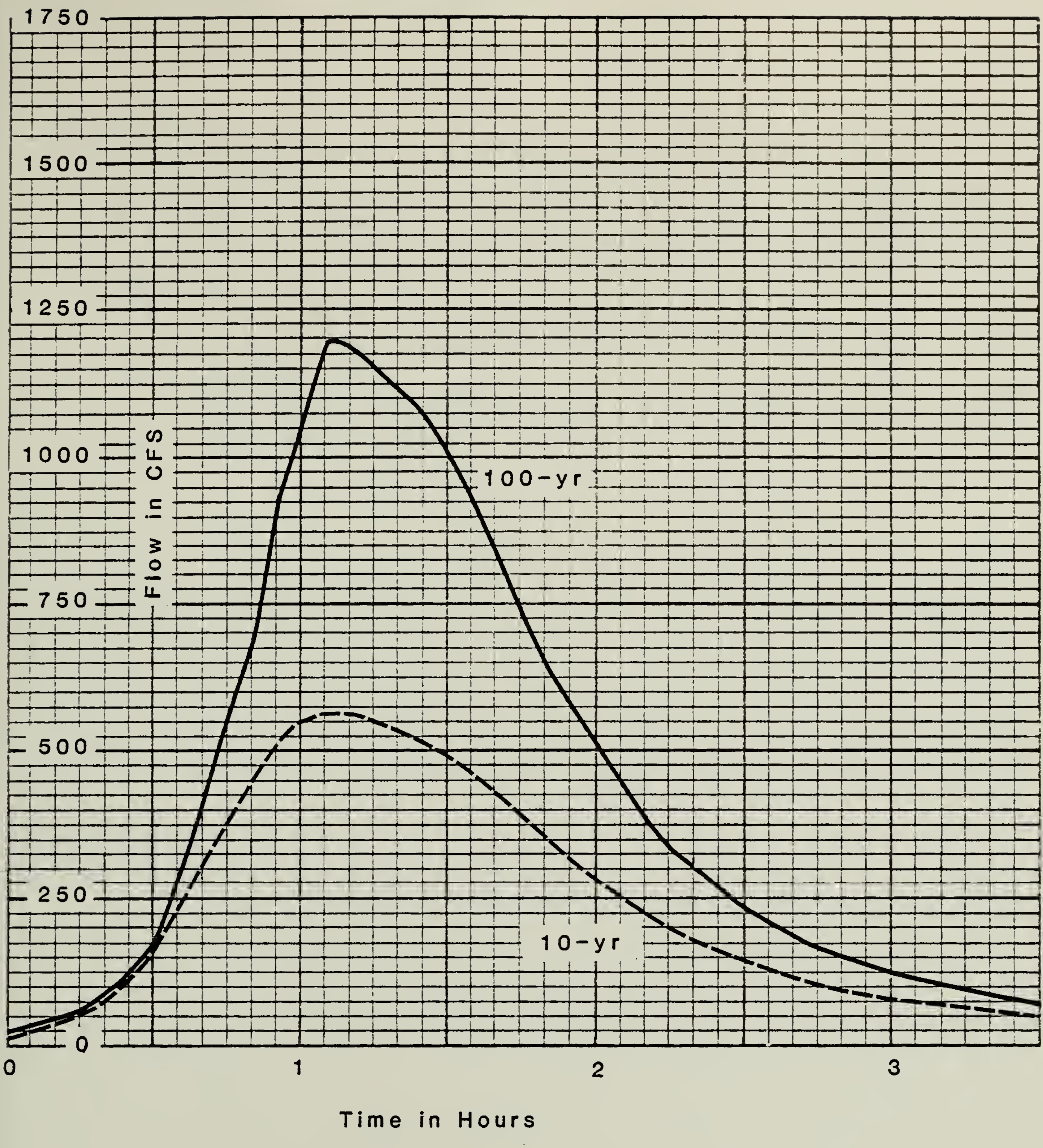

Fig. 8 Hydrographs of the 10- and 100-year floods on Access Road Wash

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